External cost of electricity generation: Contribution to the Integrated Resource Plan 2 for Electricity

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July 2010
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Executive summary

By reviewing studies completed on the external costs of electricity generation technologies the following table is suggested as an input to the Integrated Resource Plan 2 (IRP 2) in South Africa.

Units: c/ kWh (2009 cents ZAR)	***Coal***	***Nuclear***	***Gas – CCGT***	***Diesel –OCGT***	***Biomass (incl biogas)***	***Hydro (small)***	***Wind***	***CSP***	***PV***
POWER GENERATION									
GHG emissions	48 (25 – 71)	0.3 (0.2 - 0.4)	27 (11 – 32)	45.5 (24 – 67)	4.3 (1.8 – 5)	0.15 (0.1 - 0.2)	0.8 (0.4 - 1.2)	0.7 (0.3 - 1.1)	2.8 (1.6 - 4.4)
Health impacts	1.35 (1.0 - 1.7)	0.03	0.34	0.22	0.39	0.05	0.09	0.09	0.19
FUEL (Production & Transport)									
Acid mine drainage	2.1* (0.4 - 3.9)	?	?	?	-	-	-	-	-
Biodiversity loss	0.7 (0.6 - 0.8)	0.1	0.39	0.9	0.13	0	0	0	0
Health impacts	0.36 (0.02 - 0.7)	0.15	0.14	0.15	0.05	0	0	0	0
GHG emissions	2.3 (1.3 - 3.3)	0.45	2.8	2.8	1.5	0	0	0	0
TOTAL EXTERNALITY COST (estimate)	~ 55	~ 1	~ 30	~ 50	~ 6	~ 0.2	~ 0.9	~ 0.8	~ 3
Benefits of electrification – positive externalities	18 (4.7 - 24.2)	18 (4.7 - 24.2)	18 (4.7 - 24.2)	18 (4.7 - 24.2)	18 (4.7 - 24.2)	18 (4.7 - 24.2)	18 (4.7 - 24.2)	18 (4.7 - 24.2)	18 (4.7 - 24.2)
* A presentation by the Federation for Sustainable Environment (Pretorius, 2009) estimates the water damage externality from Eskom's coal mining needs at about R cents 38/kWh.									

The international studies on energy externalities and the local studies in South Africa suggest that the high impact areas for power generation are impacts of climate change and health impacts of outdoor air pollution. Climate change impacts are by far the greatest. The health costs due to outdoor air pollution are considered quite low based on national studies, though these may be underestimated. Damage cost from acid mine drainage is also thought to be significant, and could be substantially higher than reported here.

External costs of electricity generation are a necessary factor in modelling the IRP 2. To be consistent, external costs must be added to the modeller's reference case and to all policy cases or scenarios. In the multiple criteria decision-making process, the external costs should be reported as a distinct criterion. The weighting of this criterion relative to others (cost, carbon, and access) should be discussed with stakeholders.

Although the external cost presented here are appropriate for input into the IRP 2, an extensive national review must be completed for future IRPs. Furthermore, the Integrated Energy Plan (IEP) should take additional factors into account: health impacts of *indoor* air pollution (important in poor households, as well as industry); noise from transport, and other poverty-related issues such as wealth impacts of paraffin fires and burns, and social costs of fuel wood scarcity.

1. What are the major externalities in the electricity supply sector?

A recent study of external costs of energy commissioned by WWF South Africa, reviewed the local and international literature for last two decades (Spalding-Fecher, 2009). The international studies on energy externalities and the local studies in South Africa suggest that the high impact areas for power generation are impacts of climate change and health impacts of outdoor air pollution. In terms of the relative magnitude of estimated external costs, the studies generally show that climate change impact are the largest, followed by health impacts of outdoor air pollution. In addition, a study in 2005 (Spalding-Fecher, 2005) showed that electrification creates significant health benefits by displacing other fuels. Although this benefit if not specific to the type of power station generating the electricity (so it would not influence the choice of plants in the IRP), it is an important consideration when comparing electricity to other energy sources. Most of these energy externalities studies are relatively old and must rely on international data quantify many of the impact pathways. Local data on emissions is readily available, but how these emissions lead to specific health and other impacts needs additional research.

2.1 Existing studies of external costs related to electricity supply

Table 2 below shows a review of South African studies assessing the external costs related to electricity supply.

Table 1: Review of South African studies assessing external costs related to electricity supply in South Africa (Spalding-Fecher, 2009)

Study/Impact pathway	Raw Data/ Pollution	Dispersion/ people impacted	Exposure	Dose-Response/ risk level	Physical Impact	Valuation	Monetary Impact (R/yr)
Spalding-Fecher & Matibe (2003)							
Electricity: health impacts	L	I	C	I*	C	I/L	R1.1b
Electricity: climate change	L	NA	NA	NA	NA	I	R7.0b
(Palmer Development Consulting, 2003)							
Electricity: all impacts					I	I	R75-120b
(Bignaut & King, 2002)							
Electricity: climate change	L					I	R7.3b
Van Zyl et. al. (1999)							
Coal mining: water quality	L					L	R0.02-0.01b
Coal mining: climate change (CH4)	L					I	R0.02-1.3b
Coal mining: morbidity and mortality (compensation costs)						L	<R0.01b
Key: L = local source/data, I=international source/data, NA=not applicable, I*=international with some modification to local conditionsC=calculated from previous columns, health impacts=health impacts of air pollution, I/L=international data for mortality valuation and local data for morbidity valuation.							

The monetary impact of the South African has been presented as cost impact per kWh of electricity generated in Table 3. Where monetary impact was expressed in a specific year the value was inflated to 2009 Rands. External cost estimates from the South African studies for coal-fired power generation were compared to international studies. The cost estimates for all other power generation technologies are also presented from international studies Table 3). Monetary values in foreign currencies were inflated to 2009 and converted to South African Rands.

Table 2: External costs of electricity generated from different power generation technologies based on South African and international studies

Units: c/ kWh (2009 cents ZAR)	***Coal***	***Nuclear***	***Gas – CCGT***	***Diesel – OCGT***	***Biomass***	***Renewables (Small Hydro Wind, CSP, PV)***
POWER GENERATION						
GHG emissions	7.1 (3.4 - 16.6)[1]; 26.5 (9.6 - 129.5)*; 20.6*; 20.1**; 56.9***	0.1*	14*; 11.1**; 9.1****	9*	1.5*	0.3 (Wind, CSP) (0.2 (Hydro) - 2.3 (PV))*
Health impacts	1.3 (1.0 - 1.7)[1]; 10.2*; 9*; 10.2**; 9.7***	0.3*	2.6*; 4.2****	2.2*	3.9*	0.9 (Wind, CSP) (0.5 (Hydro) - 7.2 (PV))*
FUEL						
Acid mine drainage	0.37 (0.34 - 3.88)[2]					
Biodiversity loss	0.8*; 0.64*	0.1*	0.39*	0.9*	0.13*	0*
Health impacts	0.05 (0.02 - 0.07)[2]; 7.1*; 6.42*; 0.06***	1.54*	14.1*	15.3*	0.5*	0*
GHG emissions	2.4 (1.3 - 3.3)[2]; 2.3*; 2.06*; 1.94***	0.45*	2.83*	2.8*	1.5*	0*
Benefits of electrification – positive externalities	18.3 (4.7 - 24.2)[3]	18.3 (4.7 - 24.2)[3]	18.3 (4.7 - 24.2)[3]	18.3 (4.7 - 24.2)[3]	18.3 (4.7 - 24.2)[3]	18.3 (4.7 - 24.2)[3]
Notes: [1,2,3] South African Studies; * EU Studies; ** China Study; *** India Study; *** Brazil Study; [1] Values inflated from Spalding-Fecher & Matibe (2003); [2] External costs per ton from van Zyl et al. (1999) converted to per kWh based on Eskom coal use in 2009 (1.685 kWh produced per ton of coal burnt); [3] External benefits values based on VOLY method by Spalding-Fecher (2005); International studies assume 20.66 Euro/ton CO2 and 747.29 euro/ton CH4; Externality cost estimates per kWh were converted to 2009 Rands by inflating in currency of publication and then applying 2009 exchange rate.						
Main South African Studies: Van Horen 1996; van Zyl et al. 1999; Winkler, Spalding-Fecher & Tyani 2002; Bignaut & King 2002; Spalding-Fecher & Matibe 2003; Spalding-Fecher et al 2005; Spalding-Fecher 2009						
Main International studies: EnergyE 2003; CASES 2006; CASES 2008; NEEDS 2009						

South African studies (Bignaut & King, 2002) (Spalding-Fetcher & Matible, 2003) on the external costs of climate change from coal-fired power generation seem to be outdated compared to international estimates. This is largely due to those studies using too low damage estimates for climate change. More recent estimates of climate change damage costs are in the region of $30-85/ton of CO_2-eq (Stern, 2006).

International studies out cost local studies by a factor of 10 for health impacts, largely because of different approaches in valuing health between developing and developed countries and rural sitting of South African coal-fired power plants. Similarly the external costs for health impacts from coal mining are higher in European studies than in South African or Indian studies, see Table 3. It must also be noted that the external health cost from PV systems in the European study seems to be remarkably high, largely due to the imbedded energy required in the construction of the modules.

2.2 Best estimates of external costs based on existing studies

By reviewing the local and international literature on the cost of externalities from different electricity generation technologies, the following best estimate of external costs is determined (Table 3).

Table 3: Best estimate of external costs for electricity generation technologies in South Africa

Units: c/ kWh (2009 cents ZAR)	***Coal***	***Nuclear***	***Gas – CCGT***	***Diesel –OCGT***	***Biomass (incl biogas)***	***Hydro (small)***	***Wind***	***CSP***	***PV***
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Biodiversity loss	0.7 (0.6 - 0.8)	0.1	0.39	0.9	0.13	0	0	0	0
Health impacts	0.36 (0.02 - 0.7)	0.15	0.14	0.15	0.05	0	0	0	0
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* A presentation by the Federation for Sustainable Environment (Pretorius, 2009) estimates the water damage externality from Eskom's coal mining needs at about R cents 38/kWh.									

The major external costs from power generation are climate impacts from GHG emissions and health impacts from nitrous oxides (NOX), sulphur dioxide and particulates. Specific emission factors for the different power generation technologies were identified from (Winkler, 2007)and Bauer et al. (Bauer, 2008). High and low externality costs from GHG emissions were determined by applying the climate change damage cost of 85$/ton of CO_2-eq (Stern, 2006) and 30$/ton of CO_2-eq to the technology specific emission factors respectively.

The external costs on health impacts from coal-fired power stations are based on Spalding-Fecher & Matible (2003) and van Horen (1996). For the other technologies health impact costs from power generation are determined from international studies (CASES, 2008) (NEEDS, 2009) and adjusted to the South African context in line with how the health impact costs from coal-powered electricity generation in South Africa compare to the international studies. For PV the external costs from manufacture were excluded.

Four major impacts from fuel procurement and transport for the power generations technologies were identified, namely acid drain mining damage, biodiversity loss, health impacts and GHG impacts. For coal fuel the cost estimates are based on van Zyl et al. (1999) and updated with Eskom's coal use in 2009 (Eskom, 2009). The external costs of fuel for the other technologies are based on international studies (CASES, 2008). It is notable that acid mine drainage may be a much larger external cost than that presented here (Pretorius, 2009). The impact of acid mine drainage or related fuel extractions processes for nuclear, gas and diesel is unknown.

Renewable energy technologies do not have any external costs from their fuel procurement or transport and record amongst the lowest external costs with nuclear for health and GHG emission in power generation (Table 3).

Health benefits from electrification are based on Spalding-Fecher (2005).

3. How should these numbers to used in IRP2?

In the modelling for IRP2, the values presented in Table 3 should be used as externality adders, added to the costs to various power plants. To be consistent, external costs must be added to the base case / modeller's reference case and to all policy cases or scenarios.

In the multiple criteria decision-making process, the external costs should be reported as a distinct criterion. The weighting of this criterion relative to others (cost, carbon, and access) should be discussed with stakeholders.

4. What should be done in future?

External costs of electricity generation in South Africa should definitely be of concern, especially the high estimates for coal (Rc 55/kWh), gas (Rc 30/kWh) and diesel (Rc 50/kWh). The greatest share of the externality costs is from the climate change impact of GHG produced with these power production technologies.

Considering the disparities between the local figures for external health costs and international figures a more detailed assessment of these would have to be undertaken for future Integrated Resource Plans. The local studies may have undervalued the health impacts. Acid mine drainage from coal mines supplying coal-fired power stations needs to be reviewed and quantified in monetary terms, as this externality may be more than 10 times the highest cost reported.

The external costs considered here are for electricity, not all energy. This is appropriate for an input to the Integrated Resource Plan. For IRP, the major externalities are GHG emissions contributing to climate change and health impacts of outdoor air pollution. Taking a broader perspective of all energy, the Integrated

Energy Plan (IEP) should take additional factors into account: health impacts of *indoor* air pollution (important in poor households, as well as industry); noise from transport, and other poverty-related issues such as ealth impacts of paraffin fires and burns, social costs of fuel wood scarcity (Spalding-Fecher 2009). Finally, it should also be noted that not all externalities are negative, but that electrification can have positive benefits.

The inputs reflected in this study are based on existing studies and have been compiled under severe time constraints. Future research should examine external costs with more time taken.

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